



# Irrigation in the American West: Area, Water and Economic Activity

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**ABSTRACT** *This article examines irrigation in the American West based on consistent Federal data sources. Irrigation is discussed using three measures: irrigated area, water use in irrigation, and the sales value of crops produced. We find that irrigation accounts for about three-quarters of the value of crops sold from about one-quarter of the harvested cropland in the West. In accomplishing the higher sales, irrigated agriculture accounts for three-quarters of the water withdrawn and most of the water use in the West.*

## Introduction

Irrigation is the defining characteristic of crop production in the American West. The irrigated cotton fields of the Southwest, corn of the Plains, and orchards of the Northwest all attest to the magnitude, extent and importance of irrigation. This article provides an overview of the contribution of irrigation to crop production in the American West. The article focuses on three measures of irrigation: irrigated area, water use in irrigation, and the sales value of crops produced. Readers will, it is hoped, gain a sufficient overview of irrigation's importance to understand the motivation and context of discussions to follow.

## Irrigated Agricultural Area

According to the 1997 Census of Agriculture, 17.4 million hectares (mha) (43.0 million acres [ma]) of agricultural land were irrigated in the American West (Figure 1). This represents an increase of 1.5 mha (3.8 ma) (almost 10%) from levels reported in the 1992 Census of Agriculture and approaches the prior census-year maximum of 17.6 mha (43.4 ma) in 1978 (Table 1). The distribution of irrigated lands in the West shows highest concentration of irrigation in Western river valleys and in the extensive Plains area that overlies regional aquifers (Figure 1).

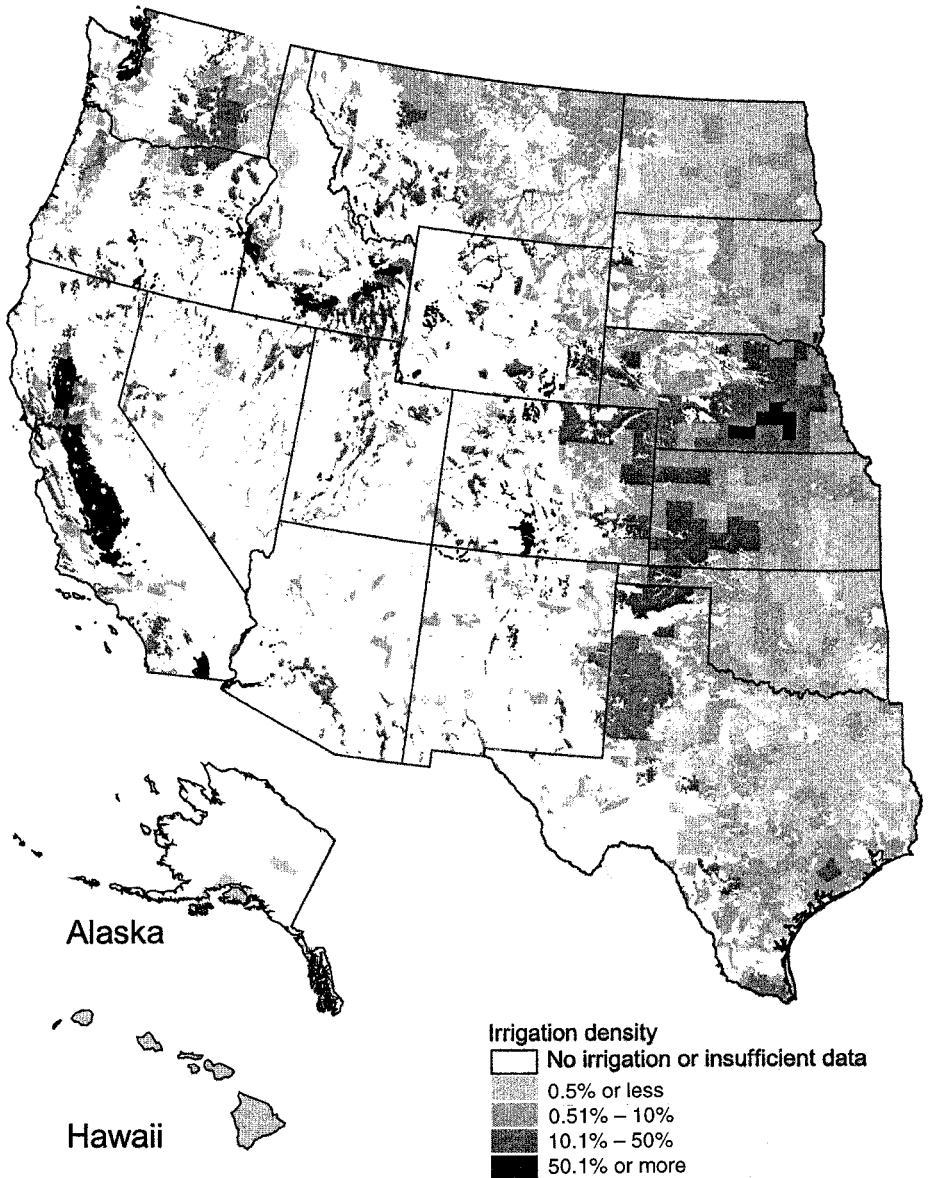
The National Agricultural Statistics Service (NASS), USDA, conducts the Census of Agriculture (Census) on a five-year interval (NASS, 1996a). We rely on data from the Census for the following discussion because these data have a long history, consistent methodology and statistical reliability. There are, however, alternative federal estimates of lands irrigated in the Western USA. State-level estimates of irrigated lands or lands with irrigation capability are included as part of the Natural Resources Inventory conducted by the Natural Resources Conservation Service, USDA (SCS, 1994) and the Water Use Estimates

Table 1. Irrigation statistics for the Western United States 1899–97

Item	1899 <sup>1</sup>	1969 <sup>2</sup>	1978	1982	1987	1992	1997
19 Western states: <sup>3</sup>							
Irrigated land (ha)	3 065 612	15 773 306	17 545 047	16 767 033	15 240 233	15 869 155	17 418 742
Irrigated pasture (ha)	645 550	2 069 204	2 408 169	1 717 136	1 740 410	1 578 652	1 954 702
Irrigated cropland harvested (ha)	2 420 062	11 730 465	15 136 878	15 049 898	13 499 822	14 290 503	15 464 039
Non-irrigated cropland harvested (ha)	32 793 899	39 439 587	41 454 889	43 805 567	38 161 431	39 366 288	42 049 402
Percentage of West's harvested cropland irrigated	6.9%	23.4%	26.7%	25.6%	26.1%	26.6%	26.9%
Percentage of national harvested cropland irrigated	2.8%	12.5%	13.8%	13.6%	14.8%	15.3%	16.2%
Percentage of national harvested cropland irrigated located in the West	96.9%	88.8%	85.6%	83.7%	79.9%	78.0%	76.4%
Change from prior Census: <sup>4</sup>							
Irrigated land (ha)		12 707 694	1 771 741	- 778 014	- 1 526 801	628 922	1 549 587
Irrigated pasture (ha)		1 423 654	338 965	- 691 033	23 275	- 161 758	376 050
Irrigated cropland harvested (ha)		9 310 404	3 406 413	- 86 981	- 1 550 075	790 680	1 173 537
Non-irrigated cropland harvested (ha)		6 645 688	2 015 302	2 350 677	- 5 644 135	1 204 856	2 683 114
Percentage of West's harvested cropland irrigated		16.5%	3.3%	- 1.2%	0.6%	0.5%	0.3%
Percentage of national harvested cropland irrigated		9.7%	1.3%	- 0.2%	1.2%	0.5%	0.9%
Percentage of national harvested cropland irrigated located in the West		- 8.1%	- 3.2%	- 1.9%	- 3.8%	- 1.8%	- 1.6%
Percentage change from prior Census: <sup>4</sup>							
Irrigated land		414.5%	11.2%	- 4.4%	- 9.1%	4.1%	9.8%
Irrigated pasture		220.5%	16.4%	- 28.7%	1.4%	- 9.3%	23.8%
Irrigated cropland harvested		384.7%	29.0%	- 0.6%	- 10.3%	5.9%	8.2%
Non-irrigated cropland harvested		20.3%	5.1%	5.7%	- 12.9%	3.2%	6.8%

Source: US Census of Agriculture

<sup>1</sup> Crop statistics refer to total area of (irrigated) crops and double counts a relatively small area from which more than one crop (other than hay) was harvested.  
<sup>2</sup> Irrigated crop statistics are based on Class I-V farms with sales of US\$2500 or more. Estimate of non-irrigated cropland harvested (all farms) is based on the assumption that the area irrigated by smaller farms is divided between cropland harvested and pasture in the same proportion as in larger Class I-V farms.  
<sup>3</sup> 19 Western states include the Plains States (Texas, Oklahoma, Kansas, Nebraska, South Dakota, and North Dakota) and all states to the West, the Mountain (Arizona, New Mexico, Colorado, Utah, Nevada, Wyoming, Idaho, and Montana) and Pacific (California, Oregon, Washington, Alaska and Hawaii) regions.  
<sup>4</sup> Change from prior Census year appearing in the table.



**Figure 1.** Distribution of irrigation in the American West. *Note:* Values mapped are 1997 irrigated county land areas in farms divided by county areas clipped to cropland locales. Clipped areas with cropland are defined by excluding urban areas, rural parks, and other areas in which cropping activities are scarce or non-existent for other reasons. Total county areas are used in Alaska and Hawaii. Counties for which irrigated areas were not disclosed are assumed to have densities less than 1/10 per cent. *Source:* National Agricultural Statistics Service (1999a) data; irrigation location estimated by ERS.

conducted by the US Geological Survey (USGS) (Solley *et al.*, 1998). Other NASS estimates are available for selected states and crops. Many state agencies supplement federal statistics with their own estimates of irrigated land or land

with irrigation capacity. Unfortunately, none of these estimates is wholly consistent across the geographic range and number of agricultural activities covered by the Census. Over the last 20 years, estimates from the various sources have differed by as much as 20%. Much of the difference stems from differences in the definition of 'irrigated area'. The Natural Resources Inventory estimates include land irrigated in the current year or any two of the past four years, while the Census reports the more restrictive measure of land irrigated in the census year (SCS, 1987). Irrigated area estimates provided under the USGS Water Use Program include turf irrigation (i.e. parks and golf courses). Perhaps the most important advantages of the Census data are the reliable and consistent geographic presentation focused on agriculture over a long history of Agricultural Census taking.

Table 1 presents a historical perspective of irrigated land in the West over the last century. In 1899, there were 3.0 million irrigated hectares in the West, which comprised 97% of the Nation's irrigated land. By 1978, irrigated land reached the historic census-year maximum of 17.4 mha, including almost 2.4 mha of irrigated pasture and 15 mha of cropland. Total irrigated area fell from 1978 to 1987, with the greatest percentage decline occurring in irrigated pasture. Area irrigated increased again in the period between the 1987 Census and the 1997 Census. Many factors contributed to the significant increase in irrigated area over the past century. Among the factors would be increasing yields on the intensive margin, rather than expanding on the extensive margin, as a way to increase crop production, and farm revenue. Federal policies to develop surface water supplies and policies that linked commodity programme benefits to crop yields also played a role in the irrigation increase. Another factor was development of new technologies that enabled economical access to large volumes of groundwater and sprinkler-application technologies that enabled expansion of irrigation onto lands not accessible under traditional gravity methods. The steadily rising demand for farm products from the West, as transportation systems improved, international trade expanded and incomes increased has also contributed to development of irrigation in the West (National Research Council, 1996; Council for Agricultural Science and Technology, 1996; Gollehon *et al.*, 1997, McGuckin *et al.*, 1989; Holmes, 1972).

The 1997 Census divides the Western irrigated agricultural lands into 15.5 mha of 'Cropland Harvested', and 1.9 mha of 'Pastureland and other land'. Irrigated cropland harvested represents about 27% of all cropland harvested in the West and represents 76% of the Nation's irrigated cropland harvested. Area in the irrigated pasture and other land category declined by 0.45 mha, from almost 14% of irrigated land in 1978 to 11% in 1997. Contributing to the steep area decline in the early part of the period were increasing water costs driven by higher energy prices. A shift from below-normal to above-normal precipitation increased water supplies for the far West and Southwest from 1992 to 1997. Increased water supplies enabled irrigation of pasture land, whose water was used on other crops in 1992, thus contributing to the sharp increase in pasture areas from 1992 to 1997.

Over the 20-year period from 1978 to 1997, the share of the West's cropland that was irrigated remained about 26%. With the exception of 1982, percentage changes in irrigated cropland area were generally comparable to percentage changes in overall cropland area. Federal programmes that idled cropland were a primary cause of variation in cropland area over this period, and these

programmes affected both irrigated and non-irrigated cropland. Through the 20-year period, the irrigated share of US cropland increased as the West's share of irrigated cropland declined. Much of the East's recent growth in irrigation occurred in the alluvial region along the Mississippi River (Missouri, Arkansas and Mississippi), reflecting increased soybean irrigation.

### Water Used for Irrigation

As with irrigated area, there is more than one measure of water used by irrigated agriculture. Every five years, the US Geological Survey, US Department of the Interior, estimates both water withdrawals and consumptive use (Solley *et al.*, 1998). Estimates are made at a local level based on locally available information, including theoretical estimates of crop-water use, crop area, delivery records of off-farm water suppliers, and details on conveyance losses, water application rates and return flows. An alternative estimate is available from the Farm and Ranch Irrigation Survey (FRIS), now conducted by NASS, which uses a sample of irrigators identified in the previous Census of Agriculture. The sampled irrigators are asked to report their water applications, in total and by crop, for a crop year one or two years following the Census year (NASS, 1999b). Therefore, these two sources estimate water used in different years, and neither coincides with Census years.

Three measurements can be used to characterize water use for agricultural irrigation: withdrawals, applications and consumptive use. The three terms refer to specific measurements and should not be used interchangeably. *Withdrawal* measures total water diverted from surface water sources and extracted from groundwater aquifers (Solley *et al.*, 1998). *Application* measures that portion of the water withdrawn and delivered to the field, excluding conveyance and delivery-system losses and gains (NASS, 1999b). Water applications are the portion of withdrawals that are directly under a producer's control. Irrigation management and use of improved irrigation technology directly influence this quantity. *Consumptive use* refers to that portion of water withdrawn and applied that is actually consumed by evaporation, transpiration and plant growth (Solley *et al.*, 1998; Aillery & Gollehon, 1997). Consumptive use is usually estimated based on plant water-requirement models, and does not include water lost to percolation or runoff.

Each of these measures may be used to describe the water requirements of irrigated agriculture. Withdrawals are the best indication of the water-quantity impacts of irrigation water diversions. Withdrawn water that is not consumptively used is available for future use, although the location, quality and timing of availability are affected. Consumptive use is an indicator of the water quantity lost to the immediate hydrologic cycle.

Irrigated agriculture withdraws and uses the most freshwater of any economic sector in the West. With withdrawals of 164 billion cubic metres (BCM) (133 million acre-feet [maf]), irrigated agriculture accounts for over 74% of the West's total freshwater withdrawals. The quantity withdrawn is almost 9100 cubic metres per hectare ( $\text{m}^3/\text{ha}$ ) (3 acre-feet per acre). When measured by consumptive use, irrigation uses about 97 BCM (79 maf) of water, or almost 90% of total Western water use. Irrigation returns a smaller proportion of withdrawals (41%) when compared with other sectors that, when combined, return 80% of withdrawals to streams and aquifers. By comparison, irrigation with-

drawals in the 31 Eastern states account for 21 BCM (17 maf), or about 8% of total withdrawals. Withdrawal rates are substantially lower at 4000 m<sup>3</sup>/ha (1.3 acre-feet per acre). Nationally, irrigation consumptive use was over 138 BCM (112 maf) and irrigation accounted for 81% of the total (Solley *et al.*, 1998).

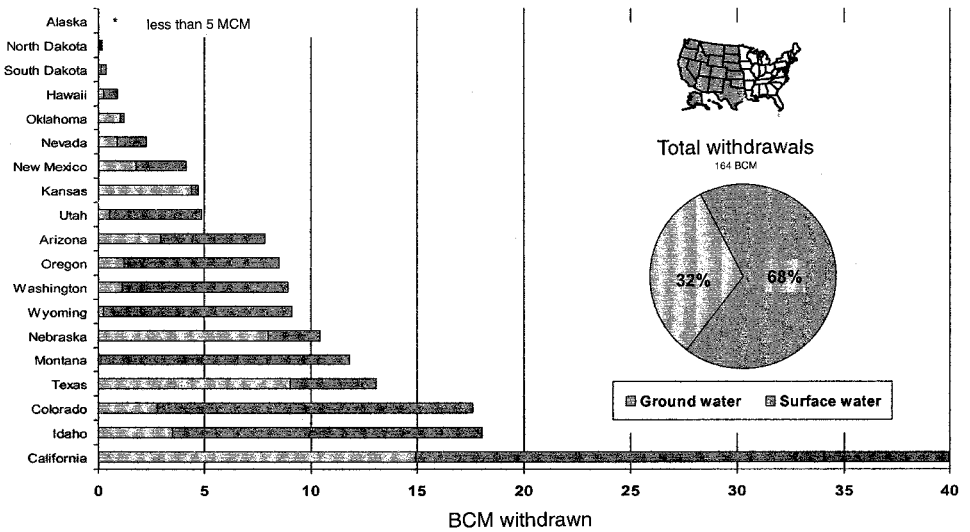
In the West, total withdrawals for off-stream uses have declined by about 10% since 1985, with declines in all sectors except domestic and commercial sectors. Together, irrigation and thermoelectric power generation withdraw about 86% of the freshwater pumped from aquifers and diverted from rivers, streams and lakes. These data do not consider instream water uses, such as hydroelectric power generation, navigation, recreation flows or flows to maintain ecosystems. Instream uses may be larger than offstream uses in many locations, but specific quantities are difficult to measure.

Water applications in the West averaged about 6100 m<sup>3</sup>/ha in 1998 (NASS, 1999b). The 3000 m<sup>3</sup>/ha difference in withdrawals and applications is due, in large part, to conveyance losses. Average application rates ranged from 4000 m<sup>3</sup>/ha for the 35% of the area irrigated with centre-pivot sprinklers to 10 000 m<sup>3</sup>/ha for the less than 1% of the area with sub-irrigation (water-table control). Water applications with other major technologies include 7300 m<sup>3</sup>/ha for all gravity systems (49% of the area), 5200 m<sup>3</sup>/ha for sprinklers other than centre pivots (12% of the land), and 6400 m<sup>3</sup>/ha for drip/trickle/micro-sprinkler precision systems (3% of the area). A dramatic shift occurred in the 1984 to 1998 period when gravity irrigated area declined from 62% to 49%, while the West's centre-pivot sprinkler-irrigated area increased from 20% to 35% (NASS, 1999b; Bureau of the Census, 1986). The relative efficiency of the application technologies is impossible to quantify because of management differences and differences in climate, crop and yield. Qualitatively, the drip/trickle precision systems have the greatest potential for efficiency with greater than 95% of applied water being used for plant growth. Certain types of centre-pivot sprinklers have achieved this level, but most sprinklers are 60–85% efficient. Most gravity systems are from 50% to 70% efficient (Negri & Hanchar, 1989).

The West is supplied primarily by surface-water sources (Figure 2). Over 111 BCM (90 maf) (68%) of withdrawals are from streams, rivers and lakes. The remaining 53 BCM (43 maf) (32%) comes from groundwater sources. Irrigation water sources vary considerably by state. California has the largest irrigation withdrawals of any state at 39 BCM annually, accounting for about one-quarter of all withdrawals in the West, and more than double those of the next largest withdrawal state, Idaho (18.5 BCM). Colorado and Texas also have withdrawals greater than 12 BCM. Of the five states with the largest withdrawals, only Texas withdraws more ground than surface water. In 1995, most states tended to be heavily dependent on a single water source—surface water in most states, although the Plains States were more dependent on groundwater (Figure 2).

### Sales Value

A preferred measure of irrigation's contribution to crop production is the direct value of total crop production, but that estimate is not available. The Census reports the amount of crop sales at the farm market gate, but sales do not capture the value of crops that are produced and consumed on the farm without entering a market channel. This underestimation is most prevalent with irrigated forage and feed crops used on the farm. In some prior Census of Agriculture

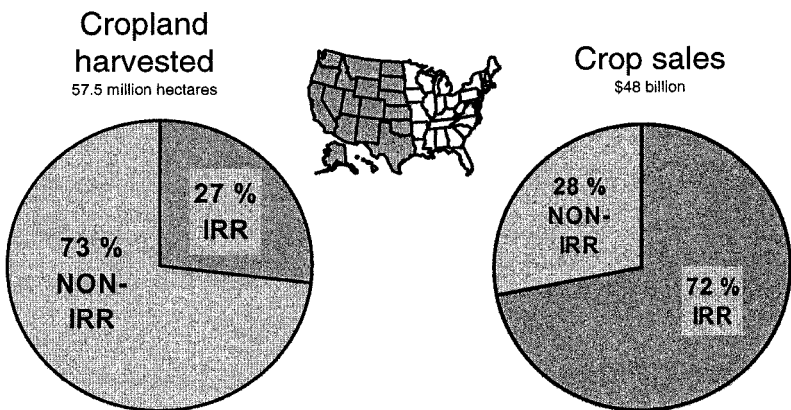


**Figure 2.** Sources of irrigation water in the West, by state, 1995. *Source:* Solley *et al.* (1998)

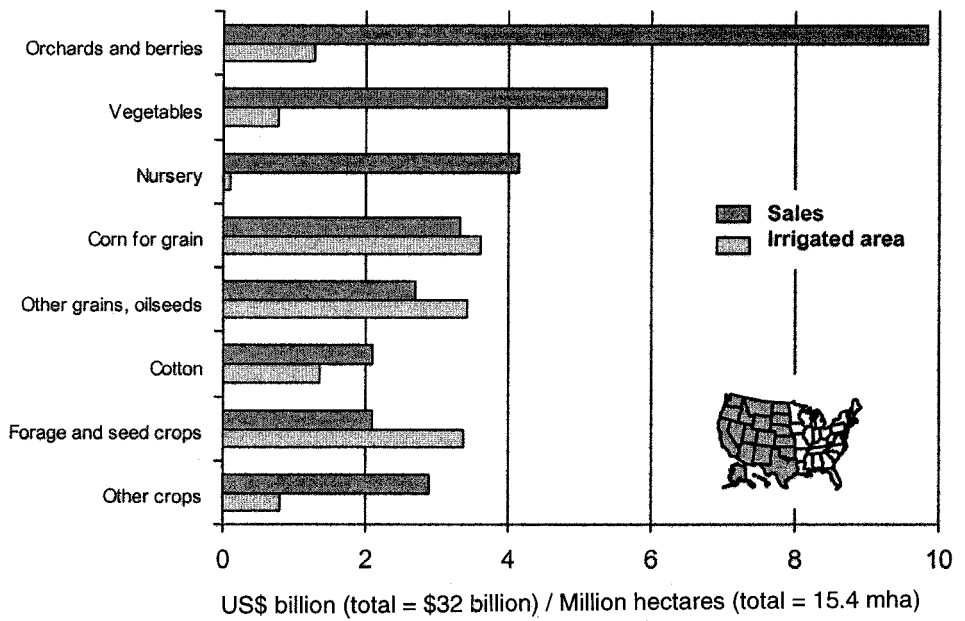
reports, a value of production estimate was made at the state level. In 1987—the last year a value of production was reported in the Census—the US total sales value was 14% less than the value of production on all harvested cropland. An estimate of the underestimation specifically for irrigation is not available.

Census crop sales reports provided the basis for current estimates of irrigated crop values. Individual 1997 Census of Agriculture farm responses were examined and crop sales classified into one of three irrigation groups for each commodity: only irrigated, only non-irrigated, and combined irrigated and non-irrigated. Irrigated commodity sales was the sum of the only irrigated farms plus an apportioned share of the sales on combined farms.

Based on calculations with 1997 Census of Agriculture information, the West contained 57.5 mha (142 ma) of harvested cropland that produced crop sales of



**Figure 3.** Irrigated and non-irrigated shares of cropland harvested and crop sales, 1997, (19 western states). *Source:* National Agricultural Statistics Service (1999a) data; irrigated sales estimated by ERS.



**Figure 4.** Irrigated acres and sales, by crop, 1997 (19 western states). *Source:* National Agricultural Statistics Service (1999a) data; irrigated area and sales estimated by ERS.

US\$45 billion. Irrigated crops in the West occupied 27% of the areas, but produced 72% of the total value of sales (Figure 3). Sales from Western irrigated crops were about \$32 billion in 1997, about one-third of the US total crop sales. Average sales per harvested hectare in the West were \$2100 for irrigated and \$300 for non-irrigated cropland.

High-valued orchards, berries, vegetables and nursery crops account for almost 60% of the West's total value of sales from irrigated crops (Figure 4). Field and forage crops account for the remaining 40% of the sales. In contrast, high-valued crops occupy only 15% of harvested irrigated land with 71% of the irrigated area accounted for by feed and forage crop groups. Corn for grain is the dominant crop in terms of area. The grouping in Figure 4 for 'Other grains and oilseeds' is largely wheat (almost half the areas), combined with grain sorghum, barley, oats, rice and soybeans. Alfalfa hay area is two-thirds of the 'Forage and seed crop' category, with other types of hay, silages, grass seed, and legume seed comprising the remainder.

The wide differences in crop values and the fact that most of the crop sales from irrigation come from 15% of the land provides significant flexibility for irrigated agriculture to adjust to changes in water availability. Farmers can adjust to physical water shortages by adjusting cropping choices to maintain production of the higher-valued crops. This ability to substitute crops is an important response to water shortfalls. In addition, innovative water markets have increased the ability of farmers and water suppliers to transfer water, enabling maintenance of higher-valued crops during droughts (Gollehon, 1999).

## Summary

This article examines three measures of irrigation: irrigated agricultural area, water used in irrigation, and the sales value of crops produced. By all three measures, irrigation is an important contributor to the value of Western agriculture. In 1997, irrigated lands produced 72% of crop sales on only 27% of the harvest crop area. In 1995, irrigation accounted for 74% of the region's water freshwater withdrawals from lakes, rivers, and aquifers. Irrigation accounts for almost 90% of the total consumptive use by all sectors of the economy. Future increased competition for water will impact on irrigated agriculture's ability to withdraw and consume water at current levels. This, in turn, raises questions about the sector's ability to maintain the current irrigated area and production values.

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